Electrical water bath stunning parameters

A workshop held at the Thistle Hotel, East Midlands Airport *4th April 2007*

Summary
A description of the different waveforms and parameters used to define stunning currents was given. It was stressed that measurements of AC current or voltage should be the root mean square (rms) and should be measured using true rms meters. Both Alternating Currents and Direct currents are currently being used to stun birds in electrical water baths. The neurological basis of electrical stunning was explained and it was stressed that effective stunning is determined by an epileptiform activity on EEG followed by a reduction to less than 10 % in the total pre stun EEG power. Behavioural indicators such as apnoea, loss of muscle tone and the loss of the nictitating membrane reflex should be used with caution when assessing water bath stunned chickens. It is difficult at present to recommended parameters for DC stunning. Studies suggested that pulsed DC (pDC) and high frequencies can result in a product of higher quality but are less effective than AC at stunning chickens. There is ongoing research on parameters required for effective pDC stunning. The workshop recommended that constant current stunners should be looked into as they reduce variability in stunning which is caused by varying resistances of shackled birds at stunning.

1. James Kirkwood HSA Opening address

The workshop was called to review current knowledge on electrical water bath stunning for broilers. In particular there would be discussions on which electrical parameters were suitable, their merits and disadvantages. Moreover, the workshop was to identify any gaps in knowledge that might require research.

2. Jeff Lines Silsoe Livestock Systems Ltd. Electrical water baths- how do they work?

Current is the rate of flow of charge particles, measured in Amperes. The voltage is the pressure that the electrons or ions are under to move. Resistance is defined as the ratio of the voltage applied to the resulting current, measured in ohms. Electrical currents may be classified as alternating currents (AC) or direct currents (DC). In alternating currents the direction of the current (and the voltage) is constantly changing. In direct currents (DC) the direction of the current (and voltage) is constant. If the direction is constant but the magnitiude is continuously changing it is commonly referred to as pulsed DC (pDC). The voltage or current of an AC or pDC current is best characterised by its root mean square value (rms). Comparisons cannot be made between the rms of an AC current and the average or peak value of a pDC current. Where an AC voltage is not sinusoidal, rms measurements must be made using a ‘true rms’ meter. Rms measurements for pDC systems must

use an AC+DC meter, or the rms should be calculated as the root of the sum of the squares of the DC and AC components.

For many biological objects, the resistance can decrease with frequency, voltage and time. Resistance measurements of biological objects should therefore be made using representative electrical signals.

The challenge to electrical water bath stunning is that of achieving a consistently high standard of welfare and product quality. As the stunning current is increased the welfare of the bird improves because the stun becomes immediate and long lasting, but the carcass quality is likely to suffer due to an increase in the probability of breast meat haemorrhages and broken bones. The main interest in investigating alternative stun frequencies and waveforms is to find a condition acceptable levels of welfare can be achieved without carcass damage. Currently this does not seem to be achievable. The problem is further compounded by the variability in the resistance of birds on a shackle line. This means that the voltage used must be sufficient to generate a current that will rapidly stun the bird with the highest resistance, without causing damage to the carcass of the bird with the lowest resistance. Constant current stunning systems, where the same current is metered out to each bird, were developed to try to overcome this problem. They do not however solve the fundamental problem that a current sufficient to stun a bird properly is associated with a elevated risk of carcass damage.

The current design of shackle lines causes discomfort due to compression of the legs in the shackles. This pressure helps to maintain good electrical contact between the birds and the shackle resulting in less variation in resistance from bird to bird and so a smaller variation in the stunning current applied.. Recent research however suggests that consistent electrical contact is better achieved by using loosely fitting shackles and applying a continuous, fine spray of water on the birds legs. Welfare problems on the shackle line can also be due to pre-stun shocks or intermittent electrical contact during stunning. Proper maintenance and monitoring of the systems can help to identify and solve these problems.

3. Charlie Mason HSA Recommendations for alternating current and direct current stunning

The Welfare of Animals (Slaughter and Killing) Regulations 1995 allow for electricity to be used in the stunning of poultry provided that the strength and duration of the current is such that the bird is immediately rendered unconscious and remains so until dead. Moreover, the current should be strong enough to ensure that every bird is stunned. Currently this is achieved by use of AC and DC currents of various strengths and frequencies. There are numerous recommendations of parameters from which the industry can choose. Most recommendations are trying to balance the need for a reasonable product quality with the requirements for animal welfare as set down in legislation. As an example the recommendations for 50 Hz AC from

the DEFRA 2006 draft codes of practice, the OIE guidelines 2006 and EFSA-Q-2003-093 standards are shown below (Table 1).

Table 1 Recommended Currents for Stunning Chickens & Turkeys

Advice from	Chickens	Turkeys
Defra	105 mA	150 mA
OIE	120 mA	150 mA
EFSA	100 mA	250 mA

Recommendations for pulsed DC exist only in published literature and as with AC the recommendations are varied and inconsistent. The industry therefore needs the confidence of agreed standards for the water bath system to underpin the integrity of production systems and assurance schemes.

Bert Lambooij University of Wageningen High or low frequency, AC or DC stunning- which is better for welfare?

When electricity is applied to animals it can cause immobilisation, narcosis or electrocution. Immobilisation can occur without the animals losing sensibility to pain. It is used as a restraint to allow easy and safer processing of animals at slaughter. Current American legislation allows immobilisation of poultry which is achieved with 25 – 30 V at 50 – 3000 Hz. Equipment like the Feenix Stockstill applies a current of about 6V from the nose to the tail of cattle immobilising them. Electro immobilisation causes distress in the animals. Electronarcosis occurs when an electrical current induces a seizure-like brain state during which the animal is insensible to pain and unconscious. The current has to be of sufficient strength otherwise muscular stimulation and immobilisation may occur without loss of consciousness. Electro sleep has been achieved in humans by stimulating the brain stem and the cortex using rectangular pulses of 0.1 to 1 ms of 0.5- 10 V at 50 – 3000 Hz. The effects of electro sleep on welfare are disputable. Another term commonly encountered is electro anaesthesia which has been demonstrated in dental and animal surgery. Rectangular pulses of 2 ms at 100- 100000 Hz have been reported to temporarily prevent any sensation of pain during surgery. A current of 7 mA caused violent spasms and irregular respiration, 9 mA caused breathing stertorous and spasm of the glottis while 20 mA caused incomplete tetanisation and cardiac arrhythmia. Electro anaesthesia can provide analgesia with immediate recovery on switching off the current. However, there are some reports of pain perception during this treatment and effects on welfare are disputable. Moreover, it is of limited use in animal slaughter as it does not induce insensibility which persists long enough for the animals to die from bleeding.

Electrical stunning relies on induction of a grand mal seizure or general epileptiform insult. The most effective currents to induce an epileptiform insult are AC at frequencies of 50 – 200 Hz in most species. It is difficult to induce seizure with frequencies below 25 Hz while higher current is required to

induce seizure with frequencies above 1600 Hz. Also the duration of the insult is much shorter at high frequencies. Electrocution occurs when the current causes an irrecoverable loss of consciousness. Stunning currents across the heart increase chances of electrocution. A minimum current of 120 mA (50 Hz) per bird is currently recommended for electrocution in water baths. Although sinusoidal AC is the most common waveform for electrocution, a variety of waveforms and frequencies can be used. Pulsed direct currents and pulsed alternating currents may be used as alternatives. Electrocution has the most desirable effect on welfare grounds when it is accompanied by insensibility, while narcosis is also acceptable. Immobilisation may cause undue stress and discomfort and is therefore unacceptable. Careful energy dosing and determination of seizure threshold may lead to an increased bird welfare and meat quality.

4. Martin von Wenzlawowicz Dr Water bath stunning guidelines within EU countries

The EU Directive 93/119/EC sets out the minimum requirements for stunning methods including water bath stunners in Europe. National regulations in Austria, Germany, Norway, Sweden and Switzerland provide detailed recommendations or guidelines for proper use of electrical water bath stunners (Table 2). Although these recommendations tend to vary, most countries recommend a current around 150mA for turkeys with the current for broilers ranging from 100 to 120 mA.

Table 2 Required Minimum Current for Stunning Turkeys & Broilers in the EU

Country	Broiler	Turkey
Austria	100 mA	150 mA
Germany	120 mA	150 mA
Netherlands	100 mA	-
Norway	120 mA	150 mA
Sweden	120 mA	150 mA
UK	105 mA	150 mA

Guidelines exist on handling, lairage, shackling, stunning, electrical parameters, bleeding and personnel training. Pre-slaughter handling should be such that the birds are spared any avoidable excitement and that they should be provided for their physical needs for food, water and shelter. The time from when the birds are shackled to the time they are stunned should be limited to 60s. Breast comforters, from shackling to entering the water bath, help to keep the birds calm and reduce flapping and attempts to right themselves. A shield at the entrance to the water bath can be used to gently lift the birds and allow their heads to swing into the bath. If this is coupled with the lowering of the shackle line, it can ensure a rapid entry into the water bath thus reducing the risk of pre-stun electrical shocks. The depth of the electrical water bath should be such that the heads of the birds are completely immersed up to the base of their wings. Electrodes should span the entire length of the water bath and the heads should never be more than 5 cm away

from the electrode. Shackles should provide good electrical contact and resistance may be lowered at the shackle, by a smooth spray of water. In the water bath, conductivity can be improved by adding salt to water lacking in minerals.

The birds must be immersed in the water bath for at least 4s although most plants in Europe use 10s. Stun parameters should be based on current recommendations from scientific studies. The water bath parameters may be checked by stunning a single bird. The ammeter should display zero before the bird is immersed and should rise immediately to the stunning level on immersion. This level should be maintained until the bird exits the water bath.

There is great variation in stun parameters used across Europe. Currents around 100 mA/bird of 100-400 Hz sine or rectangular wave AC applied for 4-12 seconds appear to be the most successful at rendering birds insensible until death from bleeding. Observations of pulsed DC between 51-79 mA (1:1 mark: space)of 600, 800 and 1000 Hz applied for 11 seconds did not satisfactorily induce insensibility that lasted until death from bleeding. Although pulsed DC resulted in less blood spots in fillets than 400 Hz, 120 mA AC, its effects on welfare do not justify a switch to pulsed DC stunning. There is currently not enough scientific evidence on which to base guidance for pDC stunning.

Instead of risking infringements to animal welfare by using ineffective currents the poultry industry should be encouraged to breed animals, which can be stunned properly without a risk of carcass damage.

5. Steve Wotton University of Bristol The development of criteria for assessing effective water bath stunning in poultry

An effective stun is characterised by the production of tonic clonic epilepsy in mammals. Cardiac arrest induced during electrical stunning is desirable for welfare as the animals have less chance of recovering during bleeding. However, it is essential that the animals are stunned first, as cardiac arrest without stunning can cause suffering. Electrical waterbath stunning of poultry can produce different EEG manifestations and the criteria for effective stunning is not so well defined. The abolition of somatosensory evoked potentials has been used since 1990 to identify effective stunning in the laboratory and in the same year, it was proposed that subjective assessment of stunning could be made through the observation of the return of neck tension in birds. Behavioural estimates such as neck tension, nictitating membrane reflex and pupil dilation can be used in a slaughterhouse routinely but are less precise and less reliable than the objective laboratory techniques.

Electrical water baths should be designed such that an observation of bird behaviour can easily be done. The design of bird entry should allow for the heads to be flicked in and become fully immersed immediately, preventing the incidence of pre-stun shocks. Research has demonstrated the importance of full head immersion to ensure that the stunning current does not bypass the brain. There has been some controversy with regard to use of bird behaviour

as an indicator of effective stunning in the processing plant. For example, electrical current has been shown to induce a curare-like state in muscles where the animal was immobilised but not stunned. Therefore, it is difficult to propose criteria for the assessment of effective stunning in a commercial processing plant that would be agreed by all parties.

Previously, researchers have proposed the use of epileptiform activity followed by EEG suppression and recent research has used this alternative objective method to evaluate waterbath stunning with chickens.

During electrical stunning, the amount of current that each individual bird receives is important. Tests on some constant voltage systems have shown that the a bird in the bath may receive more than twice the current received by another bird in the bath. This imbalance occurs because the current that each bird receives is dependent on their resistance and the variation in resistance between birds is very difficult to control. Although the system's monitors will indicate that an optimum current is being drawn by the whole water bath system, the 'low resistance' bird will be over stunned and may incur broken bones and/or haemorrhages whereas the 'high resistance ' bird will receive too little current and will probably not be stunned. Multibird waterbath stunners that are constant current by design may go a long way to reduce this problem. A prototype system in which each bird formed its own circuit that was isolated from other birds and where the current is controlled by automatically varying the applied voltage electronically will improve both welfare and product quality. Such a system was built and tested by scientists at the Silsoe Research Institue in the early 1990's but the equipment manufacturers have failed to respond to the challenge to develop a commercial model.

6. Mohan Raj University of Bristol The effect of pulsed direct current on spontaneous EEG's in broilers

Electrical stunning may be assessed by measuring the brain's electrical activity using EEG. A substantial increase in the total power (epileptiform activity) followed by a profound suppression in activity to less than 10% of the pre-stun levels constitutes a duration of unconsciousness and insensibility. This duration of unconsciousness should persist until the bird dies from bleeding. Evoked responses and reflexes are suppressed during this period of unconsciousness. However, evoked responses are suppressed in both effectively and ineffectively stunned birds. The use of evoked responses and reflexive behaviours as assessment of the effectiveness of water bath stunning therefore has limitations. Moreover, without profound suppression of EEG after seizure, potentially painful arousal cannot be ruled out.

When head only AC stunning was applied at a chosen frequency, the effectiveness of the current at inducing epileptiform EEG activity was limited to a range of frequencies. Lower frequency currents have slower rates of voltage change and longer excursion distance than the higher frequency currents, thus have a greater effect on the birds. It is therefore recommended that the current is increased if higher frequencies are used.

Frequency (Hz)	RMS current (mA)	RMS voltage (V)
up to 200	100	151
>200 to 600	150	216
>600 to 800	200	273
>800	not known	not known

Ventral cuts (2 common carotid and 2 external jugular veins) were more effective (20s before brain activity seized) than ventral cuts (1 common carotid and 1 external jugular veins) (90s before brain activity seized) at reducing the EEG signal to less than 10% of pre-stun levels. It is therefore recommended that electrically stunned birds receive a ventral cut.

At 400 mA of pulsed DC, a minimum pulse width of 30% of the current cycle is necessary to induce epileptifom EEG. Lowering the pulse width (e.g. by increasing the frequency) results in less effective stuns. Pulsed DC induced cardiac arrest without epileptiform EEG activity in some birds. Sinusoidal AC is therefore a more effective alternative to pDC.

Behavioural indicators of unconsciousness such as loss of muscle tone, apnoea and seizures are of some use when head-only stunning is used. In whole body stunning the stimulation of the body's musculature can mask some behaviours indicative of a poor stun. Epileptiform activity in the EEG followed by a quiescent phase is a better indication of a good stun. The absence of profound EEG suppression after epileptiform activity may result in a potentially painful state of arousal. High frequency stimulation of the brain can cause an increase in the ability of the brain to resist ischemia therefore ventral neck cutting is essential after high frequency stunning. Higher frequencies are less effective at inducing unconsciousness than lower frequency. Current research has demonstrated that sine wave AC is superior to pulsed DC. The efficacy of pulsed DC also decreases with decreasing pulse width.

7. Rob Barker The effect of water bath stunning current and waveform on carcase and meat quality in broilers

There is a lot of variation in electrical parameters used in water bath stunning for the commercial slaughter of broilers. One such variation is the use of alternating or direct currents in the stunning system. The variations in parameters are a reflection of the attempt to resolve the conflict between animal welfare and product quality as the parameters most effective at stunning animals have been shown to cause a lot of damage. Alternating currents are more effective at inducing a stun at lower currents than DC. However, DC systems are used as they are perceived to cause less product quality degradation than AC system. A study was conducted to compare the effects of AC and DC stunning on external and internal quality of stunned broilers. External (carcass) quality defects investigated were red wing tips, wing haemorrhaging and shoulder haemorrhaging. Internal defects investigated included broken bones of the pectoral region and breast muscle

haemorrhaging in the major and minor fillets. The AC currents of 200 Hz (100 mA), 600 Hz (150 mA) and 800 Hz (200 mA) were compared to DC of 600 Hz (78 mA). Increasing the frequency of AC resulted in less damage. However, AC resulted in higher overall carcass downgrades than DC. For example, nearly 28% of minor fillets had significant haemorrhaging at AC 200 Hz compared with just over 7% at DC 600Hz. Increased levels of broken bones with AC resulted in negative feedback from customers. With down grading a bird from A grade to B grade equating to a loss of 20p/bird, there are likely to be significant cost when changing from DC to AC stunning.

8. Simone Prinz Effects of DC and AC electrical stunning on the EEG's of broilers

A non-invasive method of measuring EEG's in chickens was developed and validated. The device consists of a frame with two pointed electrodes that clamp on to the head of the chicken. The advantage of this device is that the chickens do not have to undergo invasive preparatory surgery as the electrodes are not implanted. Moreover, measurements are quicker to set up allowing more animals to be measured during experiments. The EEG equipment was validated by recording the brain activity of birds under ketamine-xylazine, carbon-dioxide and local anaesthesia. The EEG patterns were characteristic of each of the three methods with clear spindling in the birds that were under the local anaesthetic. After validation, the EEG equipment was used to study the effect of different electrical water bath parameters that were representative of those used in processing plants on induction of unconsciousness. Commercial broilers were stunned with 100 V, 70 Hz pulsed DC, 100 V, 1500 Hz pulsed DC or 100 V, 1500 Hz rectangular AC. All treatments had a mark: space ratio of 1:1. The EEGs and physical reflexes were assessed in the birds before and after stunning. Stunning with 100 V, 75 Hz pulsed DC lead to profound suppression of EEG power in the 2-30 Hz and the 13-30 Hz band confirming that the birds were unconscious and insensible. The 100 V, 1500 Hz pulsed DC treatment did not adequately suppress EEG in the 2-30 Hz band although the 13-30Hz band was suppressed. The AC treatment failed to adequately suppress EEGs in both bands. These preliminary studies suggest that pulsed DC can be effectively used to stun broilers at 70Hz with 100V. These preliminary results are to be followed by a full analysis which will be reported in the scientific literature in due course. The results are likely to be very relevant to waterbath stunning methods. The full analysis of the results will include a report on physical reflexes and how they relate to EEG measurements.

Discussion:

Question raised on wetting the birds resulting in surface flow of current rather than through the bird. Reassurance was given that indications were that this was not the case.
Constant current stunners could reduce the variability in current received. What were the hindrances to developing constant current stunners? The electronics were easily achievable and the only problem was a mechanical

design problem on robust monitoring of current at the shackles. Research could come up with solutions resulting in a constant current stunner.
Single bird water baths were also suggested as a possible means of ensuring consistent welfare and quality.